CONTROLLED GROWTH OF CARBON NANOTUBES FOR 3D LITHIUM ION MICROBATTERIES

Vijaya Kumar Kayastha, Yoke Khin Yap, *

Michigan Technological University, Department of Physics, Houghton, MI-49931, USA

*ykyap@mtu.edu

Chunlei Wang, Rabih Zaouk, Lili Taherabadi, Marc Madou*

Department of Mechanical and Aerospace Engineering, University of California, Irvine, Irvine, CA 92697, USA.

*mmadou@uci.edu

Keywords: Carbon nanotubes, Lithium ion batteries, C-MEMS, electrochemistry

Abstract

Flat carbon plates have been used as the negative electrodes in many commercial Li-ion batteries. Their energy density is limited by the size of the cells or vice versa. These 2D batteries are not useful for applications in miniature electronic devices such as sensors, cardiac pacemakers, and hearing aids. Advanced materials and novel battery designs are desirable and will determine future advances of miniature Li ion batteries. By using carbon microelectromechanical systems (C-MEMS), we have fabricated 3D microbatteries based on arrays of carbon posts that have high aspect ratio (>10). We have demonstrated that Li ions can be charged and discharged in these carbon posts. The obtained capacity is ~220 mAh g -1, which is within the range of reversible capacities reported for coke. We have further integrated carbon nanotubes and carbon nanofibers on these 3D C-MEMS microbatteries for enhancing their storage capacity.

INTRODUCTION

Our C-MEMS fabrication process is based on the pyrolysis of photolithographically patterned photoresists [1-3]. Upon miniaturization of the active battery material in an array of posts, an increased Li capacity is important. This is very desirable so that besides increasing power density and decreasing battery charge/discharge rates, we also can maintain a high overall battery capacity. Since it has been shown that single-walled carbon nanotubes reversibly intercalate Li up to a rate of $Li_{2.7}C_6$ after applying an appropriate ball-milling treatment [4], we are now combining C-MEMS structures with CNTs and CNFs. The use of CNTs and CNFs in microbatteries has not been demonstrated. Further, the issue of the contact interface between these nanomaterials and current collectors has not been addressed.

EXPERIMENT AND RESULTS

We have fabricated 3D microbatteries based on arrays of carbon posts that have high aspect ratio (>10) as shown in Figure 1. Further, we have integrating both CNFs and CNTs into C-MEMS posts for achieving higher electrode surface areas and higher Li intercalation rates. As shown in Figure 2, CNTs can be uniformly grown on these C-MEMS posts. Furthermore, we have also been able to grow arrays of very high-density vertically-aligned multiwalled carbon nanotubes (MWNTs) by catalytic thermal chemical vapor deposition [5]. The application of these C-MEMS/CNTs, C-MEMS/CNFs, and pure CNTs arrays 3D Li ions microbatteries will be discussed in the conference.

ACKNOWLEDGEMENT

Y.K.Y. acknowledges supports from the Michigan Tech Research Excellence Fund and the Army Research Office (W911NF-04-1-0029, through the City College of New York).

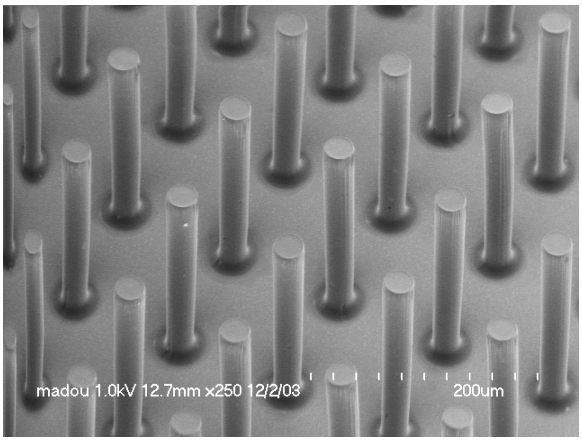

Figure 1. Arrays of carbon posts fabricated by C-MEMS technique.

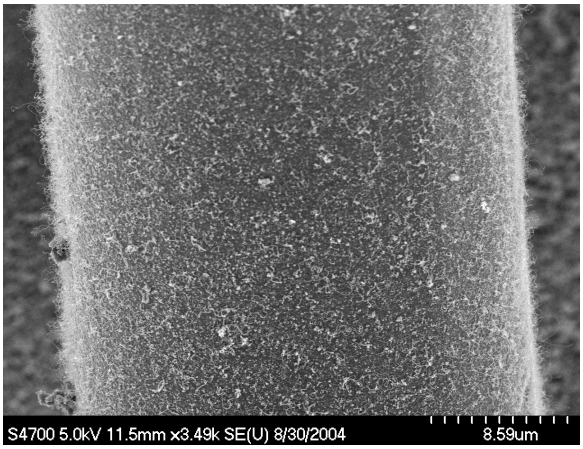

Figure 2. Growth of carbon nanotubes on arrays of the 3D C-MEMS posts.

References:

1. Kinoshita, K., et al., "Development of a carbon-based lithium microbattery, " J. Power Sources 81-82, 170 (1999).
2. Ranganathan, S., et al**.,** "Photoresist-Derived Carbon for Microelectromechanical Systems and Electrochemical Applications, " J. Eletrochem. Soc. 147, 277 (2000).
3. Wang, C., et al**.,** "C-MEMS for the Manufacture of 3D Microbatteries, " Electrochem. & Solid State Lett 7, A435 (2004).
4. Gao, B., et al., "Enhanced saturation lithium composition in ball-milled single-walled carbon nanotubes, " Chem. Phys. Lett. 327, 69 (2000).
5. Kayastha, V., et al., "Controlling Dissociative Adsorption for effective Growth of Carbon nanotubes," Appl. Phys. Lett. 85, 3265 (2004).